A BIMORPH MIRROR WITH TWO PIEZOELECTRIC LAYERS SEPARATED BY A CENTRAL CORE OF SEMIRIGID MATERIAL

The present invention relates to a bimorph mirror. A bimorph mirror is conventionally made by superposing two piezoelectric ceramics, and at least one control electrode is placed at the interface between the two ceramics to vary the curvature of the mirror as a function of an electrical voltage applied to the piezoelectric ceramic. As a result, the thinner the mirror, the greater the variation in its radius of curvature.

In addition, ceramic fabrication suffers from limitations concerning the maximum width that can be obtained, with the consequence that it is necessary to build up assemblies with ceramic segments, thereby influencing the stiffness and/or the stability of the bimorph mirror. In particular, stiffness and stability are parameters that are important for the mirror polishing that necessarily takes place after the bimorph mirror has been assembled.

An object of the invention is to provide a bimorph mirror presenting stiffness that is greater than that of a prior art mirror.

Another object of the invention is to provide a bimorph mirror presenting stability that is greater than that of a prior art mirror.

Yet another object of the invention is to provide a bimorph mirror that is capable of being made with large dimensions, for example of meter order.

At least one of the above-specified objects is achieved by a bimorph mirror presenting first and second layers of piezoelectric ceramic together with at least one electrode serving to vary at least one curvature of the mirror as a function of at least one electrical voltage applied to the piezoelectric ceramics, the mirror being characterized in that the first and second layers of piezoelectric ceramic are separated by a central core

of material such as glass or silica, which forms a semirigid beam.

The thickness e of the central core lies, for example, in the range 1 millimeters (mm) to 80 mm, and it may be greater than 2 mm or even 3 mm, or indeed greater than 5 mm. The total thickness E of the bimorph mirror may for example lie in the range 10 mm to 150 mm.

The bimorph mirror may be characterized in that the first and second layers of piezoelectric ceramic are formed by a plurality of ceramic elements placed side by side in at least one direction along section planes, and in that the section planes of said second layer are offset in at least one direction relative to the section planes of said first layer.

It may then be characterized in that said offset between the piezoelectric elements in at least one direction is equal to half a pitch P at which the piezoelectric elements are disposed in said direction.

The invention can be better understood with the help of the following description given by way of non-limiting example and with reference to the drawings, in which:

- Figure 1 shows a bimorph mirror of the prior art;
- Figure 2 shows a bimorph mirror of the present invention; and
- Figures 3a to 3d show a bimorph mirror constituting a preferred embodiment of the invention, Figure 3a being a side view, Figure 3b being an enlarged view of a detail of Figure 3a, and Figure 3c being a view seen looking along B, while Figure 3d shows the control electrodes.

In Figure 1, a prior art bimorph mirror comprises two stacked piezoelectric layers 1 and 2 sandwiched between two so-called "skin" layers 3 and 4 of glass or silicon, at least one of which is for use as a mirror. These mirrors, which are used in particular in adaptive optics, present curvature that varies as a function of an electric voltage applied to the piezoelectric ceramics.

Nevertheless, the thickness of bimorph mirrors is limited to a value of about 25 mm by the thickness of piezoelectric ceramics (for which fabrication defines a maximum thickness), and by the thickness of the skin layers 3 and 4, since as this thickness increases, the dynamic curvature of the mirror decreases.

In the invention, a central layer or core 5 of a material such as silica or glass is interposed between the layers 1 and 2.

This core 5 presents several advantages:

· it enables the effectiveness of each ceramic to be increased by moving it further away from a neutral fiber of the mirror, which neutral fiber is situated substantially in the midplane of the core 5;

· it enables thickness to be added, thereby increasing the inertia of the mirror and thus its stiffness and its stability; and

· because it is continuous over the length of the mirror, it presents a highly favorable effect on stability since it acts as a semirigid beam. This makes it possible to produce mirrors of great length, e.g. 1 meter long, without loss of stability or loss of curvature range.

The thickness $\underline{e}$ of the central core 5 can be defined as a function of the looked-for curvature characteristics. Increasing this thickness increases the stiffness of the mirror, but also increases the effectiveness of the piezoelectric actuators, because they are moved progressively further from the neutral fiber. Each thickness thus has a corresponding characteristic for curvature as a function of applied voltage. The appropriate thickness can thus be determined experimentally or with the help of calculation based on deformation by finite elements. In practice, it is advantageous to use a thickness $\underline{e}$ lying in the range 1 mm to 80 mm. The thickness E of the bimorph mirror may

lie for example in the range 10 mm to 150 mm, and in particular it may be greater than 25 mm.

The figures show piezoelectric layers that are made up of a plurality of ceramic elements 11, 12 and 21, 22, ... placed side by side at a pitch or in an array having two pitches along curvature planes (112, 123, 134, ..., 178, 212, 223, 234, ..., 267) that are perpendicular to the main faces 6, 7, 8, 9 of said layers 1 and 2.

Advantageously (see Figures 3a and 3c), the invention provides for the section planes (212, 223, 234, ..., 267) of the layer 2 to be offset parallel to said main faces relative to the section planes (112, 123, 134, ..., 178) of the layer 1, e.g. by being offset by one half-pitch in at least one direction parallel to said main faces. This enables the structure to be made more rigid, even if it does not have a core 5.

Figures 3a to 3d show the disposition of the electrodes for controlling the ceramic layers 1 and 2. Firstly, between the layers 1 and 3 there is a common electrode 45 that is continuous over the entire length of the mirror and that is associated with a side contact point 45_1 (Figure 3d), and between the layers 2 and 4 a common electrode 65 that is continuous over the entire length of the mirror, with a side contact point 65_1 (Figure 3d). Then, between the layer 1 and the core 5 there is a plurality of control electrodes given overall reference 30. In this example there are 14 control electrodes 31 to 44, and as many contact areas on a side edge of the device for controlling the layer 1. Finally, between the layer 3 and the core 5 there exists a plurality of control electrodes given overall reference 30. In this example, there are 14 control electrodes 51 to 64 disposed facing the electrodes 31 to 44 in order to control the layer 3, and as many contact areas on a side edge of the device.

The piezoelectric elements of the layers 1 and 2 are mounted in conventional manner with opposite polarities,

so applying the same voltage to the facing control electrodes (31, 51; 32, 52; etc. ...) produces a compression displacement for one of the layers and a traction displacement for the other, thereby causing the mirror to be curved since the layers 1 and 2 are disposed on opposite sides of the neutral fiber.